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(71) Applicant: DONALDSON COMPANY, INC. [US/US]; 1400 West 94th Street, Minneapolis, MN 55440-1299 (US).		<p><b>Published</b></p> <p><i>With international search report.</i>  <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	
(72) Inventors: WAGNER, Wayne, M.; 120 Redwood Drive, Apple Valley, MN 55124 (US). GILLINGHAM, Gary, R.; 17305 Flemming Lane, Prior Lake, MN 55372 (US). TOKAR, Joseph, C.; 6205 137th Street, Apple Valley, MN 55124 (US). RISCH, Daniel, T.; 1116 136th Street West, Burnsville, MN 55337 (US). ROTHMAN, Jim, C.; 332 Riverwoods Lane, Burnsville, MN 55337 (US). WAHLQUIST, Fred, H.; 8444 11th Avenue South, Bloomington, MN 55420 (US). MATTHYS, Bernard, A.; 204 Strese Lane, Apple Valley, MN 55124 (US). SABELKO, Stephen, W.; 750 Laura Street, Prescott, WI 54021 (US). PATTEN, Bryan, D.; 9624 10th Avenue South, Bloomington, MN 55420 (US). REICHTER, Gregory, L.; 10617 Hopkins Road, Bloomington, MN 55420 (US).			
(54) Title: FLUTED FILTER MEDIA			
(57) Abstract			
<p>Fluted filter media includes filter material (100) having a plurality of flutes formed therein having alternating ends of adjacent flutes closed (120) to force fluid through filter material. A first embodiment of the filter media includes tapered flutes which have the open ends (122) of the flutes larger in cross-section than the closed flutes (120), wherein the upstream open flutes converge toward the downstream end and the upstream closed end flutes diverge toward the downstream end. A second embodiment includes filter media which is asymmetric formed with dissimilar upstream and downstream flute cross-sections with larger flute openings to the upstream side of the filter. A third embodiment includes filter media with an upstream edge crushed to improve flow at the upstream edge. A fourth embodiment includes filter media with the upstream sealing material recessed from the upstream edge for reducing effects from blockages at the upstream edge of the filter.</p>			

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## FLUTED FILTER MEDIA

### Background of the Invention

Field of the Invention. The present invention relates to fluted filter media, and in particular, to fluted filter media having flutes which minimize restriction across the  
5 filter.

Prior Art. Pleated filters which utilize filter media to remove contaminants from fluids are commonly known and take on many configurations.

A common problem with filters is inadequate filter surface area. Prior attempts to improve filtering surface area for a given filter volume have not been entirely  
10 successful. Pleated filters are commonly used which utilize a pleated filter media in an attempt to overcome this shortcoming. Although pleated filter material may increase the filter area, as the pleats are placed closer and closer together, thereby placing more and more filter media in a given volume, the pleats are pressed tighter and tighter together, thereby restricting the flow. This restriction may cause the velocity of flow  
15 to increase in order to pass through the filtering media, thereby increasing the pressure differential across the filter which may cause additional problems in the system.

Most permeable filter media does not provide structural support so that the filters require housings for supporting the filtering material. This increases manufacturing costs as well as the mass and size of the filter.

20 To improve restriction and provide increased media area, as well as filter efficiency, fluted filter configurations may be utilized. Fluted filters have the capability of increased media area per unit volume, as well as less restriction and substantially straight-through flow.

Although fluted filters provide improved flow characteristics and efficiency  
25 over prior filter designs, fluted filters have the possibility of greater efficiency and improved flow characteristics. The sealed upstream ends of flutes provide a substantial blockage of the flow, and when combined with the filter material, more than half of the available cross sectional area of the fluid flow is blocked. Filter designs which have greater cross sectional area transverse to the flow provide  
30 improved flow and restriction characteristics.

It can be seen that new and improved filters are needed which provide self support, improved restriction, improved flow characteristics, and greater efficiency. In

particular, fluted filters should have a leading edge which provides less resistance and takes up less of the cross-sectional flow area than standard flute designs. In addition, the cross-sectional area of the filter media and the closed ends of the flutes at the upstream edge should be smaller than the opening area at the upstream edge of the flutes. Such improved filter designs should also be easily manufactured without undue additional steps. The present invention addresses these as well as other problems associated with filter designs.

### Summary of the Invention

10 The present invention is directed to a fluted filter device, and in particular, to fluted filter media with improved flow characteristics.

According to a first embodiment of the present invention, fluted filter media includes a fluting center sheet intermediate a top and bottom layer. It can be appreciated that the filter media may be wound or otherwise stacked so that only a 15 single sheet need be attached to a fluting sheet, as adjacent layers will serve as either the top or bottom sheet of the next adjacent layer. In addition, the layers may be wound in a spiral configuration. Alternating ends of adjacent chambers formed by the fluted material are blocked on either the upstream or downstream side. The first embodiment has tapered flutes which widen from one end to the other. The fluted 20 chambers having their upstream end closed widen to an open downstream end. Conversely, the downstream closed fluted chambers widen to an open upstream end.

It can be appreciated that with this configuration, the area of the filter media transverse to the upstream flow includes a large portion open to the chambers for receiving the flow. As the flow filters through the various filter material sheets, the 25 filtered fluid passes through an enlarged downstream end as well. In this manner, the restriction due to the filter is substantially decreased over standard fluted filter materials. In addition, the percentage of bead material and the upstream edge of the filter sheets is substantially less than the open area receiving the upstream flow.

According to a second embodiment of the present invention, fluted filter media 30 includes asymmetric flutes which have a substantially sharp peak and a widened trough. The area above the trough is open to the upstream flow. In this manner, the upstream openings at the edge of the filter media have a larger cross sectional area

transverse to the flow than the area of the closed flutes and the upstream edge of the filter material. This configuration provides improved flow with greater filter efficiency and reduced restriction across the filter.

According to a third embodiment of the present invention, fluted filter media 5 includes a crushed upstream edge providing for improved flow. According to the third embodiment, the leading edge of the filter media includes beads blocking alternating chambers of the filter flutes. The upstream edge of the bead and fluting sheet are angled so that a widened edge intercepts the flow and angles toward the downstream end. As the flow intercepts the upstream edge, only the leading sheeting edge contacts 10 the upstream flow and the bead and fluting sheet angle rearward. With this configuration, the resistance and proportion of the filter media intercepting the upstream flow at the leading edge of the filter is reduced. Therefore, improved flow is attained which provides for increased efficiency and reduced restriction across the filter.

15 These and various other advantages and features of novelty which characterize the invention are pointed out with particularity in the claims annexed hereto and forming a part hereof. However, for a better understanding of the invention, its advantages, and the objects obtained by its use, reference should be made to the drawings which form a further part hereof, and to the accompanying descriptive 20 matter, in which there is illustrated and described a preferred embodiment of the invention.

#### Brief Description of the Drawings

In the drawings, wherein like reference letters and numerals designate 25 corresponding elements throughout the several views:

Figure 1 shows a perspective view of a first embodiment of double-faced fluted filter media having tapered flutes according to the principles of the present invention;

Figures 2A-2B show diagrammatic views of the process of manufacturing the filter media shown in Figure 1;

30 Figure 3 shows an end elevational view of the filter media shown in Figure 1;

Figure 4 shows an end elevational view of a roller for forming the filter media shown in Figure 1;

Figure 5 shows a detailed end view of the teeth for the roller shown in Figure 4;

Figure 6 shows a perspective view of a second embodiment of filter media having asymmetric flutes according to the principles of the present invention;

5 Figure 7 shows an end elevational view of the filter media shown in Figure 6;

Figure 8 shows an end elevational view of a roller for forming the filter media shown in Figure 6;

Figure 9 shows a perspective view of a third embodiment of filter media having crushed leading flute edges according to the principles of the present invention;

10 Figure 10 shows an end elevational view of the filter media shown in Figure 9;

Figure 11 shows a side sectional view of the leading edge of the filter media shown in Figure 9;

Figure 12 shows a graph of pressure drop across the filter versus airflow through the filter for various fluted filter media designs;

15 Figure 13 shows a graph of pressure drop versus dust loading for various fluted filter media designs;

Figure 14 shows a sectional view of a fourth embodiment of filter media having upstream sealed flutes with a sealed portion recessed from the upstream edge of the filter media according to the principles of the present invention;

20 Figure 15 shows a side elevational view of a method of forming the leading edge of the filter media shown in Figures 9-11; and,

Figure 16 shows a side elevational view of a sheet of filter media cut into strips utilizing the method shown in Figure 15.

25

### Detailed Description of the Preferred Embodiments

Referring now to the drawings, and in particular to Figure 1, there is shown a portion of a layer of double-faced permeable fluted filter media, generally designated 100. The first embodiment of the fluted filter media 100 includes a multiplicity of tapered flute chambers 102. The flute chambers 102 are formed by a center fluting sheet 108 forming alternating peaks 104 and troughs 106 between facing sheets 110, including a first facing sheet 112 and a second facing sheet 114. The troughs 106 and peaks 104 divide the flutes 102 into an upper row and lower row. In the configuration

shown in Figure 1, the upper flutes form flute chambers 122 closed at the downstream end, while upstream closed end flute chambers 120 are the lower row of flute chambers. The fluted chambers 120 are closed by first end bead 124 completely filling a section of the upstream end of the flute between the center fluting sheet 108 and the 5 second facing sheet 114. Similarly, a second end bead 126 closes the downstream end of alternating flutes 102. Adhesive tacks connect the peaks 104 and troughs 106 of the flutes 102 to the facing sheets 112 and 114. The flutes 102 and end beads 124 and 126 provide a filter element which is structurally self-supporting without a housing.

During filtration, unfiltered fluid enters the flute chambers 122 which have 10 their upstream ends open, as indicated by the shaded arrows. Upon entering the flute chambers 122, the unfiltered fluid flow is closed off by the second end bead 126 at the downstream end. Therefore, the fluid is forced to proceed through the fluting sheet 108 or face sheets 110. As the unfiltered fluid passes through the fluting sheet 108 or face sheets 110, the fluid is filtered through the filter media layers, as indicated by the 15 unshaded arrow. The fluid is then free to pass through the flute chambers 120, which have their upstream end closed and to flow out the open downstream end out the filter media 100. With the configuration shown, the unfiltered fluid can filter through the fluted sheet 108, the upper facing sheet 112 or lower facing sheet 114, and into a flute chamber 120 blocked on its upstream side.

20 Referring now to Figures 2A-2B, the manufacturing process for fluted filter media, which may be stacked or rolled to form filter elements, as explained hereinafter, is shown. It can be appreciated that when the filter media is layered or spiraled, with adjacent layers contacting one another, only one facing sheet 110 is required as it can serve as the top for one fluted layer and the bottom sheet for another 25 fluted layer. Therefore, it can be appreciated that the fluted sheet 108 need be applied to only one facing sheet 110 when the layers are stacked or rolled.

As shown in Figure 2A, a first filtering media sheet 30 is delivered from a series of rollers to opposed crimping rollers 44 forming a nip. The rollers 44 have intermeshing wavy surfaces to crimp the first sheet 30 as it is pinched between the 30 rollers 44. As shown in Figure 2B, the first now corrugated sheet 30, and a second flat sheet of filter media 32 are fed together to a second nip formed between one of the crimping rollers 44 and an opposed roller 45. A sealant applicator 47 applies a sealant

46 along the upper surface of the second sheet 32 prior to engagement between the crimping roller 44 and the opposed roller 45. At the beginning of a manufacturing run, as the first sheet 30 and second sheet 32 pass through the rollers 44 and 45, the sheets fall away. However as sealant 46 is applied, the sealant 46 forms first end bead 38  
5 between the fluted sheet 30 and the facing sheet 32. The peaks 26 and troughs 28 have tacking beads 42 applied at spaced intervals along their apex or are otherwise attached to the facing sheet 32 to form flute chambers 34. The resultant structure of the facing sheet 32 sealed at one edge to the fluted sheet 30 is single-faced layerable filter media. If the layers are stacked or spiraled, a second bead is applied at an opposite edge to the  
10 fluted sheet 30. If the layers are not stacked or spiraled, a second bead is applied at an opposite edge and a second facing sheet is applied.

Referring again to Figure 1, it can be appreciated that the flutes 102 taper. The fluted chambers 120 having their upstream end closed, widen along the trough to an enlarged downstream opening, as shown in Figure 3. Similarly, chambers 122 have a  
15 large upstream opening, also shown in Figure 3, and taper to a narrowed closed end. In this manner, the portion of the filter media intercepting the upstream flow that is open is substantially increased. In addition, as the fluid flows along the flutes and passes through the walls of the filter media, either center sheet 108 or facing sheets 112 or 114, the fluid will flow out an enlarged open end on the downstream side of the  
20 filter.

It can be appreciated that to manufacture the tapered flutes 102, a special roller 144 is required, shown in Figure 4. The roller 144 includes a peripheral surface having a multiplicity of aligned teeth 146 formed thereon. The tapering teeth 146 taper from a narrow first end to a widened second end, as shown more clearly in Figure 5. It can be  
25 appreciated that complementary teeth 147 on an opposing roller 145 taper from a narrowed second end to a widened first end. Therefore, as the facing sheet of the center sheet 108 is fed through the nip of the complementary rollers 144, the filter media is crimped to form peaks 104 and troughs 106 which taper in alternate directions along their length. It can be appreciated that the beads 124 and 126 provide  
30 filter media which is structurally self-supporting.

As shown in Figure 3, the resulting filter media 100 includes tapered flute chambers 120 which have a closed upstream end and flute chambers 122 which have

an open upstream end. It can be appreciated that with tapered flutes 102, flute chambers 122 have a larger cross sectional area transverse to the flow than the chambers 122 which have their upstream ends closed. It can also be appreciated that the cross sectional area transverse to the flow of the fluted chambers 120 is larger than  
5 the cross sectional area of the closed chambers 122 and the edges of the sheets 108, 112 and 114. In this manner, the filter media 100 intercepts greater flow with less resistance. As the flute chambers 120 and 122 taper inversely to one another, the ends of the chambers are reversed in size at the downstream edge. With this configuration, it can be appreciated that the flute chambers 120 have a much smaller cross section at  
10 the closed downstream end of the filter media 100 and the flute chambers 122 have a much larger cross sectional area. Therefore, the flow passes in through the larger openings of chambers 120 and out through the enlarged open downstream ends of flute chambers 122. With this configuration, flow passes through filter material having much greater open space with less resistance, while still providing sufficient filter  
15 media area in the same volume.

Referring now to Figure 6, there is shown a second embodiment of filter media, generally designated 200, having asymmetric flutes according to the principles of the present invention. The filter media 200 includes asymmetric flutes 202 forming substantially narrower peaks 204 and widened arcing troughs 206. The radius of the arc of the peaks 204 is less than the radius of the arc of the troughs 206 of the asymmetric flutes 202. The filter media 200 includes a center sheet 208 and facing sheets 210, including a first upper facing sheet 212 and a second lower facing sheet 214.  
20

The facing sheets 210 are connected by upstream beads 224 and downstream beads 226. In this manner, the sheets 208, 212 and 214 form chambers 220 having their upstream ends closed and chambers 222 having their downstream ends closed.  
25

It can be appreciated that with the configuration shown in Figure 6, the upstream portion of the filter media 200 intercepting flow includes an enlarged opening for the chambers 222. In this manner, increased flow is intercepted by the fluted chambers 222 which then flow through the sheets 208, 212 and 214 and through the chambers 220. In addition, the asymmetric fluted filter media 200 provides for a self-supporting filter structure.  
30

Referring now to Figure 7, the open end of the chambers 222 is substantially larger than the bead 224 at the upstream end and the surface area transverse to the flow of the sheets 208, 212 and 214. This arrangement decreases the restriction at the filter inlet and provides for improved flow and dust loading capacity.

5 Referring now to Figure 8, roller 244 for forming the asymmetric fluted filter media 200 includes a multiplicity of teeth 246 along its periphery. The teeth 246 of a first roller 244 will have a widened outer surface with a narrow trough formed therebetween. The complementary roller would have narrowed teeth with a widened trough formed therebetween for intermeshing with the teeth 246. It can be appreciated  
10 that as the rollers engage filter material fed therebetween, asymmetric peaks and troughs are formed in the fluted filter material.

Referring now to Figure 9, there is shown another embodiment of the present invention having crushed filter media, generally designated 300. The crushed filter media includes flutes 302 having a crushed upstream edge 316. The flutes include  
15 peaks 304 and troughs 306 formed by a fluted center sheet 308. Facing sheets 310 sandwich the center sheet 308 to form fluted chambers 320 and 322. A first facing sheet 312 contacts the upper surface of the flutes, while a lower facing sheet 314 contacts the bottom of the flutes. The filter media 300 includes an upstream bead 324 and a downstream bead 326. The cross section of the flutes from the downstream end  
20 appears as in Figure 10. The cross sectional view from the upstream ends would be reversed from that shown with the open and closed portions being opposite.

As shown in Figure 11, the upstream side of the filter media 300 includes a crushed edge 316 along the upstream bead 324. This forms a sloping surface 328 of the bead 324 and center sheet 308 which engages the flow. The slope provides less  
25 resistance while greater flow is achieved, so that the restriction across the filter media is reduced. It can be appreciated that the filter material and bead engaging the flow at the edge 330 is less than the open area intercepting the flow, improving efficiency and flow.

The sloped edge can be formed by a number of methods, however a preferred  
30 method is shown in Figures 15 and 16. An arced or round forming member 350 is pressed against the upstream bead 324 before the sealing material of the beads is set to provide a quick and easy method of forming an sloping surface 328, as shown in

Figure 15. The forming tool 350 may be a ball which is rolled along the upstream bead 324 or a rounded member which is pressed onto the media 300. After the depression is made, the media 300 is cut with a blade 360 or other cutting tool at the upstream bead 324, thereby forming two strips of filter media 300 having a sloping upstream edge 330, as shown in Figure 16. It can be appreciated that a number sets of widened alternating beads 324 and 326 may be applied to a sheet of media 300. The upstream beads 324 are then crushed as shown in Figure 15. When the sealing material of the beads 324 and 326 sets, the sheet of filter media 300 is cut at beads 324 and 326 to form multiple sheets of filter media 300 having crushed upstream edges 330.

Referring now to Figure 14, there is shown a fourth embodiment of the present invention with fluted filter media 400. The fluted filter media 400 is similar to other fluted filter media, but the fluted filter media 400 has a modified upstream edge and bead configuration, as explained hereinafter. As shown in Figure 14, the fluted filter media 400 includes flutes 402 having peaks and troughs with flutes 420 closed upstream and flutes 422 closed downstream. However, unlike other fluted filters having alternating chambers sealed at the extreme upstream face of the filter media, the flutes 420 include a bead 424 sealing off the flute chamber which is recessed from the upstream edge of the filter media 400. The flutes 422 have beads 426 which are at the downstream end.

The filter media 400 provides performance advantages as it can be appreciated that large particles 1000 may accumulate at the upstream face of the filter media. As shown in Figure 14, if the particles 1000 are large enough, some of the flutes 402 may become completely blocked off. For prior filter media, if several flutes are blocked off, the blockage 1000 has greater impact as alternating surrounding flutes are sealed at their upstream side, creating increased flow redirection around the blocked flutes. However, as shown in Figure 14, when the flutes 420 are sealed at their upstream side at 424 and recessed from the upstream edge, a blockage 1000 of an adjacent downstream closed flute 422 allows the flow to pass into the upstream end of the flutes 420 and through the fluting sheet or other filter material upstream of the seal 424. In this manner, the fluid flows into flute 422 where it is forced back through the filtering material into the flutes 420 which are open to the downstream side of the filter. This

reduces clogging and provides for better flow without pressure buildup or otherwise adversely affecting filter performance. In a preferred embodiment, the upstream sealing beads 424 are recessed from approximately 1/4" to 1" from the upstream edge. In this manner, the fluted material is still self supporting while decreasing the effects 5 of clogging at the upstream face of the filter media 400.

As shown in Figure 12, the pressure drop for air flow compares fluted filter media having standard B size flutes to the tapered filter media 100 also having a B size flute. In addition, a standard A size fluted filter media is compared to the crushed filter media 300 having an A size flute. It can be appreciated that the pressure drop across 10 the filter, in both instances, is reduced as compared to the standard fluted filter configuration while having the same filter volume and nominal flute size.

In addition, as shown in Figure 13, as the filter media becomes loaded with dust, it can be appreciated that a standard B flute has a much higher pressure drop than a B flute with tapered filter media 100. In addition, a size A flute for filter media 300 15 with a crushed leading edge has a significantly lower initial pressure drop than a standard A flute.

It can be appreciated that with the present invention, filter media is provided which has a substantially greater open area transverse to the flow which intercepts the flow. This provides for increased efficiency with decreased restriction.

20 It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size and arrangement of parts within the principles of the invention to the full extent 25 indicated by the broad general meaning of the terms in which the appended claims are expressed.

**WHAT IS CLAIMED IS:**

1. Filter media inserting into fluid flow having an upstream side and a downstream side, said filter media comprising a plurality of flutes formed therein,  
5 wherein one end of each of said flutes is closed and opposite ends of said flutes are open, wherein alternating upstream and downstream portions of adjacent flutes are closed with sealing material, wherein said open ends of said flutes on said upstream side have a greater area transverse to said flow than a combined area of said sealing material and said filter media transverse to said flow at the leading upstream edge of  
10 said filter media.
2. Filter media according to claim 1, wherein the flutes having upstream closed ends comprise a closed portion recessed from the upstream end of the flutes.
- 15 3. Filter media according to claim 1, wherein the flutes comprise closed portions, wherein first alternating flutes have closed portions recessed a first distance from the upstream side of the filter media and wherein second alternating flutes have closed portions recessed a second distance from the upstream side greater than the first distance.  
20
4. Filter media according to claim 1, wherein said flutes having closed upstream ends taper to a larger area transverse to the flow on the downstream side.
- 25 5. Filter media according to claim 1, wherein said flutes having closed upstream ends have an upstream surface slanting rearward from the upstream side.
6. Filter media according to claim 1, wherein the flutes comprise peaks and valleys and wherein peaks of the flutes comprise a narrower arcing portion than the valleys.  
30
7. Filter media inserting into fluid flow having an upstream side and a downstream side, said filter media comprising a plurality of longitudinal flutes formed

therein, wherein one end of each of said flutes is closed and opposite ends of said flutes are open, wherein alternating upstream and downstream ends of adjacent flutes are closed, wherein said open ends of said flutes on said upstream side have a greater area transverse to said flow than a combined area of said closed ends on said upstream side and an upstream edge of said filter media transverse to said flow.

8. Filter media according to claim 7, wherein said flutes having closed upstream ends taper to a larger area transverse to the flow on the downstream side.
- 10 9. Filter media according to claim 7, wherein said flutes having closed upstream ends have an upstream surface slanting rearward from the upstream side.
- 15 10. Filter media according to claim 7, wherein the flutes comprise peaks and valleys and wherein peaks of the flutes comprise a narrower arcing portion than the valleys.
- 20 11. Filter media having flow passing from upstream to downstream through the media comprising a plurality of flutes formed therein, wherein one end of each of said flutes is closed and wherein alternating first and second ends of adjacent flutes are closed, wherein each of said flutes comprises tapered sides tapering from a larger open end to a smaller closed end.
- 25 12. Filter media according to claim 11, wherein the media comprises a substantially sinusoidally extending center media sheet connected to a top sheet and a bottom sheet, forming a plurality of flute chambers.
13. Filter media according to claim 12, wherein the center sheet is configured so that the chambers diminish from the upstream side to the downstream side.
- 30 14. Filter media according to claim 11, wherein the flutes are configured so that the upstream open ends comprise a larger area transverse to the flow than the downstream closed ends.

15. A method of making filter media, comprising the steps of:  
providing a length of filter material having a first face and a second face and a  
first edge and a second edge;  
5 passing the length of filter material between a first roller and a second opposed  
roller, wherein the first roller has a roller surface having alternating peaks and valleys  
formed therein, wherein the peaks and valleys extend axially along the roller and the  
peaks widen from a first end toward a second end of the roller and the valleys narrow  
from the first end toward the second end; and wherein the second roller has a roller  
10 surface having complementary peaks and valleys meshing with the peaks and valleys  
of the first roller;  
wherein the rollers form peaks and valleys into the filter material having peaks  
widening from the first edge to the second edge and valleys narrowing from the first  
edge to the second edge;  
15 depositing a sealing material proximate the first edge on the first face of the  
filter media;  
applying a facing sheet having a first side and a second side to the first face of  
the filter material, thereby forming a seal between the filter material and a first side of  
the facing sheet; and,  
20 applying a sealing material proximate the second edge on the second face of  
the filter material.
16. A method according to claim 15, wherein sealing material is applied so that  
space between the filter material and the first facing sheet is closed proximate the first  
25 edge, and space between the filter material and the second facing sheet is closed  
proximate the second edge.
17. A method according to claim 15, comprising the further step of forming the  
length of fluted filter media in an overlapping configuration, thereby sealing the  
30 second face of the fluted filter material to the second side of an adjacent layer of the  
facing sheet.

18. Filter media having flow passing therethrough from an upstream side to a downstream side, comprising a plurality of longitudinally extending flutes formed therein, wherein one end of each of said flutes is closed and wherein alternating first and second ends of adjacent flutes are closed, wherein alternating flutes include a peak  
5 formed therein extending longitudinally along the flute.
19. Filter media according to claim 18, wherein the peaks have a profile with a smaller radius arc than the troughs.
- 10 20. Filter media according to claim 18, wherein the alternating flutes include closed upstream ends below the peak.
21. Filter media according to claim 18, further comprising a center fluting sheet having peaks formed therein.  
15
22. Filter media according to claim 18, wherein the flutes comprise peaks and valleys and wherein peaks of the flutes comprise a narrower arcing portion than the valleys.
- 20 23. A method of making filter media, comprising the steps of:  
providing a length of filter material having a first face and a second face and a first edge and a second edge;  
passing the length of filter material between a first roller and a second opposed roller, wherein the first roller has a roller surface having alternating peaks and valleys  
25 formed therein, wherein the peaks and valleys extend axially along the roller and the peaks have a profile having a smaller radius arc than the valleys; and wherein the second roller has a roller surface having complementary peaks and valleys meshing with the peaks and valleys of the first roller;  
wherein the rollers form peaks and valleys into the filter material having peaks  
30 with a smaller radius arc than the valleys;  
depositing a sealing material proximate the first edge on the first face of the filter media;

applying a facing sheet having a first side and a second side to the first face of the filter material, thereby forming a seal between the filter material and a first side of the facing sheet; and,

5 applying a sealing material proximate the second edge on the second face of the filter material.

24. Filter media having a plurality of longitudinally extending flutes formed therein, wherein one end of each of said flutes is closed and wherein alternating first and second ends of adjacent flutes are closed, and wherein the first closed ends are  
10 compressed.

25. Filter media according to claim 24, wherein the first closed ends include a leading surface angling toward the downstream side.

15 26. Filter media according to claim 24, wherein the first closed ends include a leading surface arcing toward the second end.

27. Filter media according to claim 26, wherein leading surface arcs in a convex surface.

20 28. A method of making filter media, comprising the steps of:  
providing a length of filter material having a first face and a second face and a first edge and a second edge;

25 passing the length of filter material between a first roller and a second opposed roller, wherein the first roller has a roller surface having alternating peaks and valleys formed therein, wherein the peaks and valleys extend axially along the roller; and wherein the second roller has a roller surface having complementary peaks and valleys meshing with the peaks and valleys of the first roller;

30 wherein the rollers form peaks and valleys into the filter material;  
depositing a sealing material proximate the first edge on the first face of the filter media;

- applying a facing sheet having a first side and a second side to the first face of the filter material, thereby forming a seal between the filter material and a first side of the facing sheet;
- 5 applying a sealing material proximate the second edge on the second face of the filter material; and,
- compressing the first edge to form an arcing leading surface along the first edge.
29. Filter media inserting into fluid flow having an upstream side and a downstream side, said filter media comprising a plurality of flutes formed therein, wherein one end of each of said flutes is closed, wherein first flutes have seals closing off said first flutes recessed a first distance from a first end, and second flutes alternating with said first flutes have seals closing off said second flutes recessed a second distance from said first end greater than said first distance.
- 15
30. Filter media according to claim 29, wherein said first distance comprises a distance of at least 0.25 inches (6 mm).
31. Filter media according to claim 30, wherein said first distance comprises a distance of less than or equal to 1 inch (25 mm).
- 20
32. Filter media inserting into fluid flow having a first side and a second side, said filter media comprising a plurality of longitudinal flutes formed therein, wherein one end of each of said flutes is closed and opposite ends of said flutes are open, wherein alternating first and second ends of adjacent flutes are closed, wherein said closed ends 25 on said first side have a closed portion recessed from the first side.
33. Filter media according to claim 32, wherein said first closed ends include an open space intermediate the first side and the first closed portions.
- 30 34. A method of making fluted filter media having a crushed leading edge, comprising the steps of:

forming a layer of fluted filter material having a first face and a second face and a fluting sheet forming peaks and valleys with first beads on a first face of the fluting sheet and second beads on a second face of the fluting sheet;

compressing the first beads to form a depression in the layer of filter media;

5 and,

cutting the filter media at the first beads, forming a first edge having an arcing leading surface.

35. A method according to claim 34, wherein the first beads are compressed while  
10 material of the beads is not fully set.

36. A method according to claim 35, wherein the beads are cut when the material of the beads is set.

15 37. A method according to claim 34, wherein the layer of filter media comprises a plurality of first and second beads and wherein a plurality of depressions are formed at the plurality of first beads and a plurality of cuts are made at the first beads and the second beads to form a plurality of filter media layers having a first edge having an arcing leading surface.

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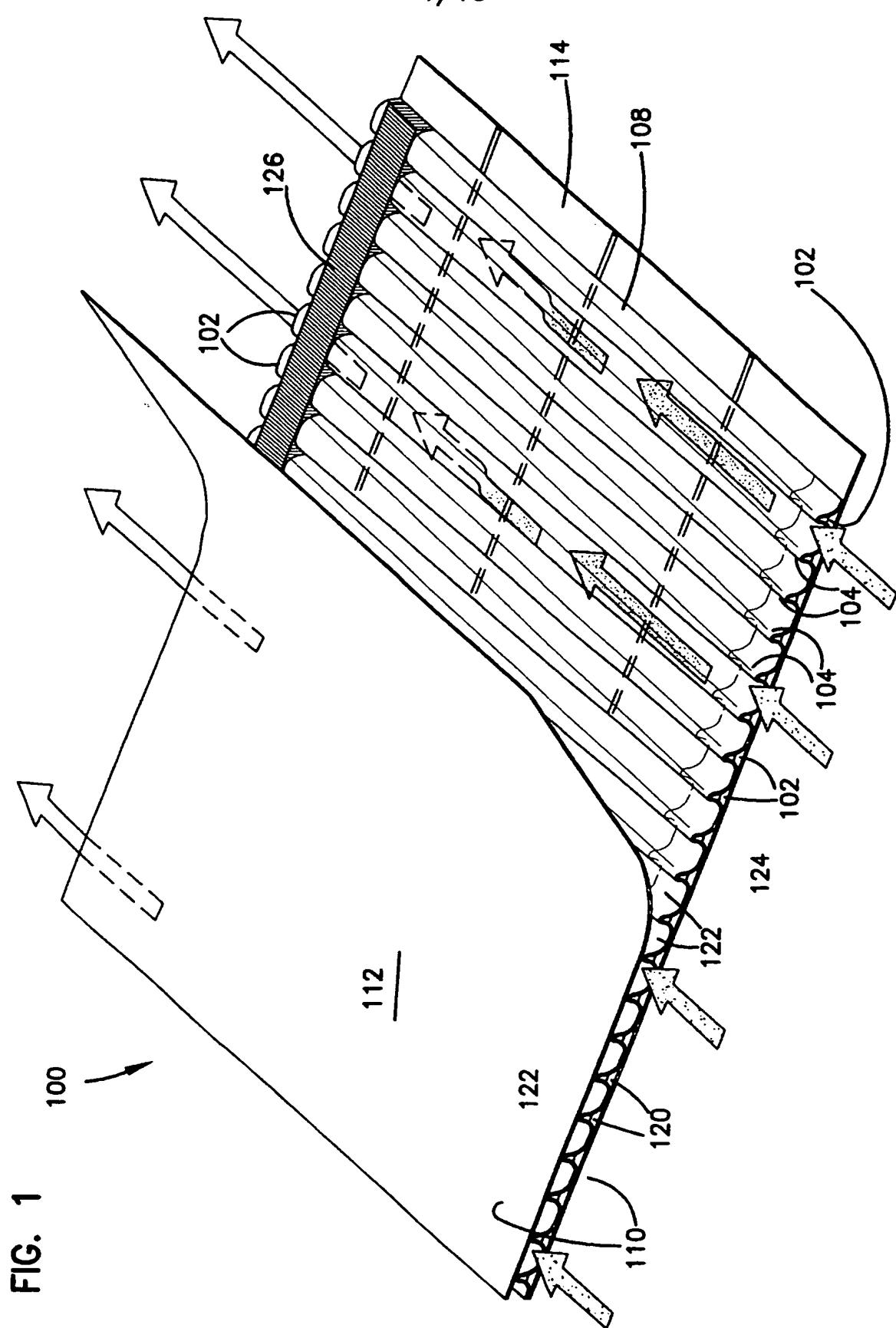
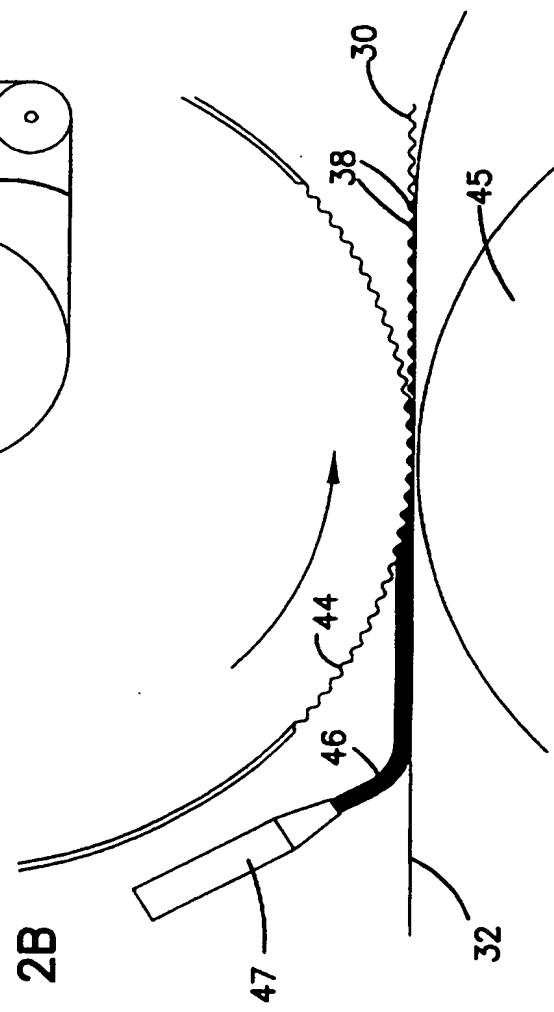
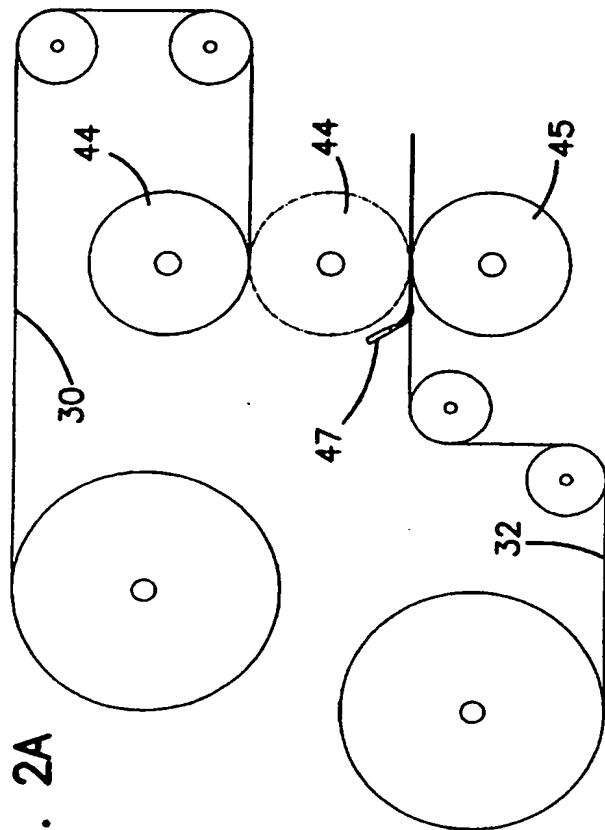


FIG. 1

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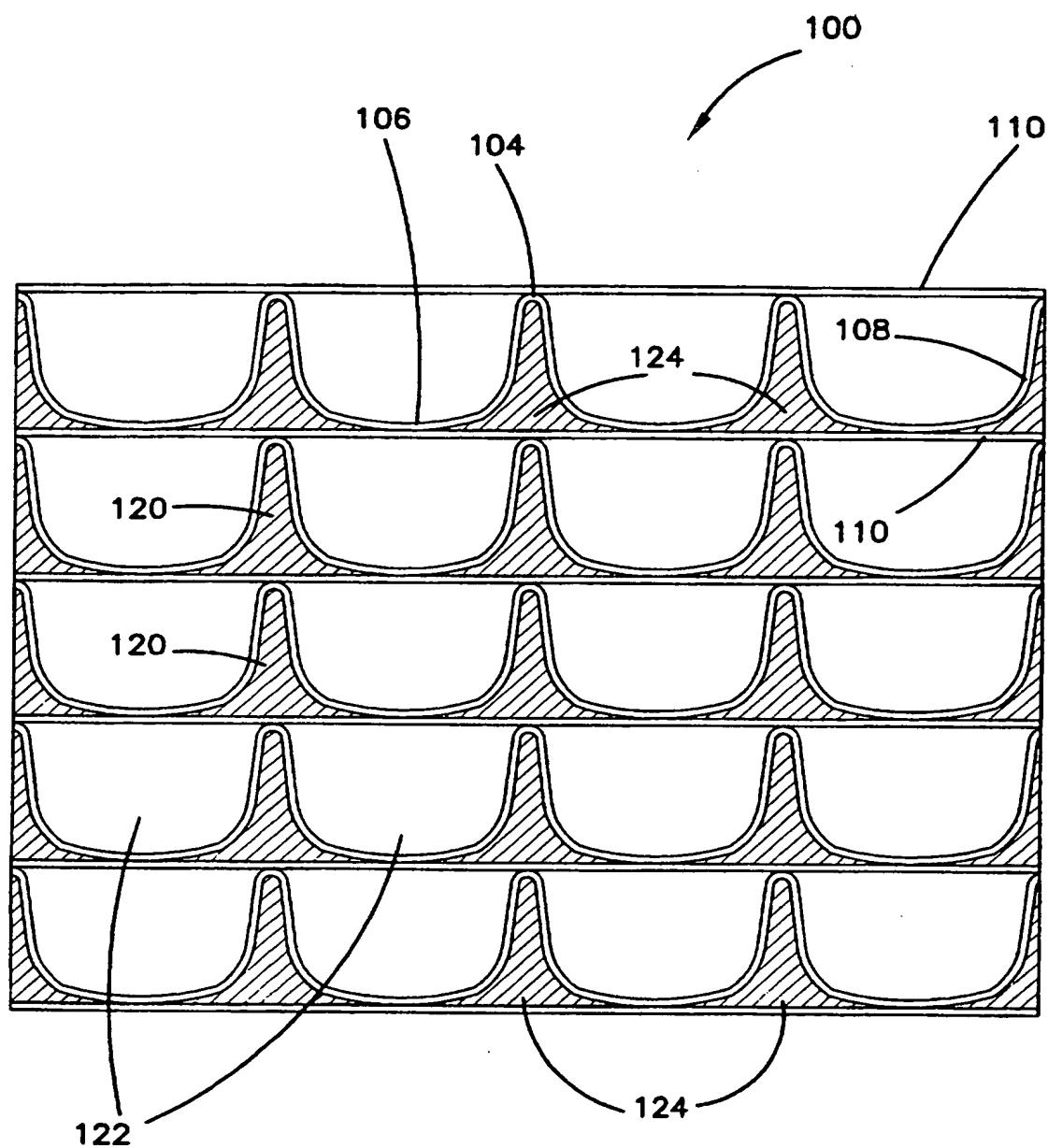


FIG. 3

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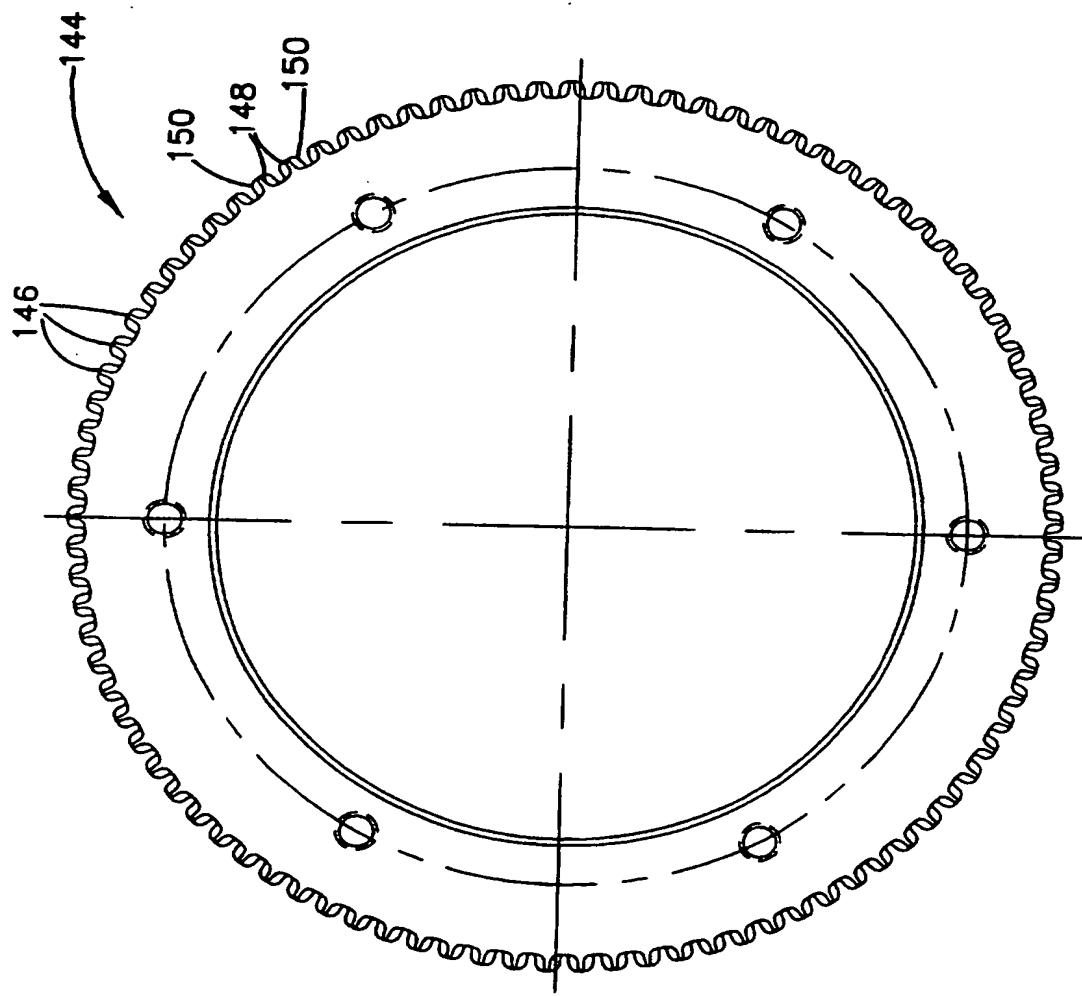


FIG. 4

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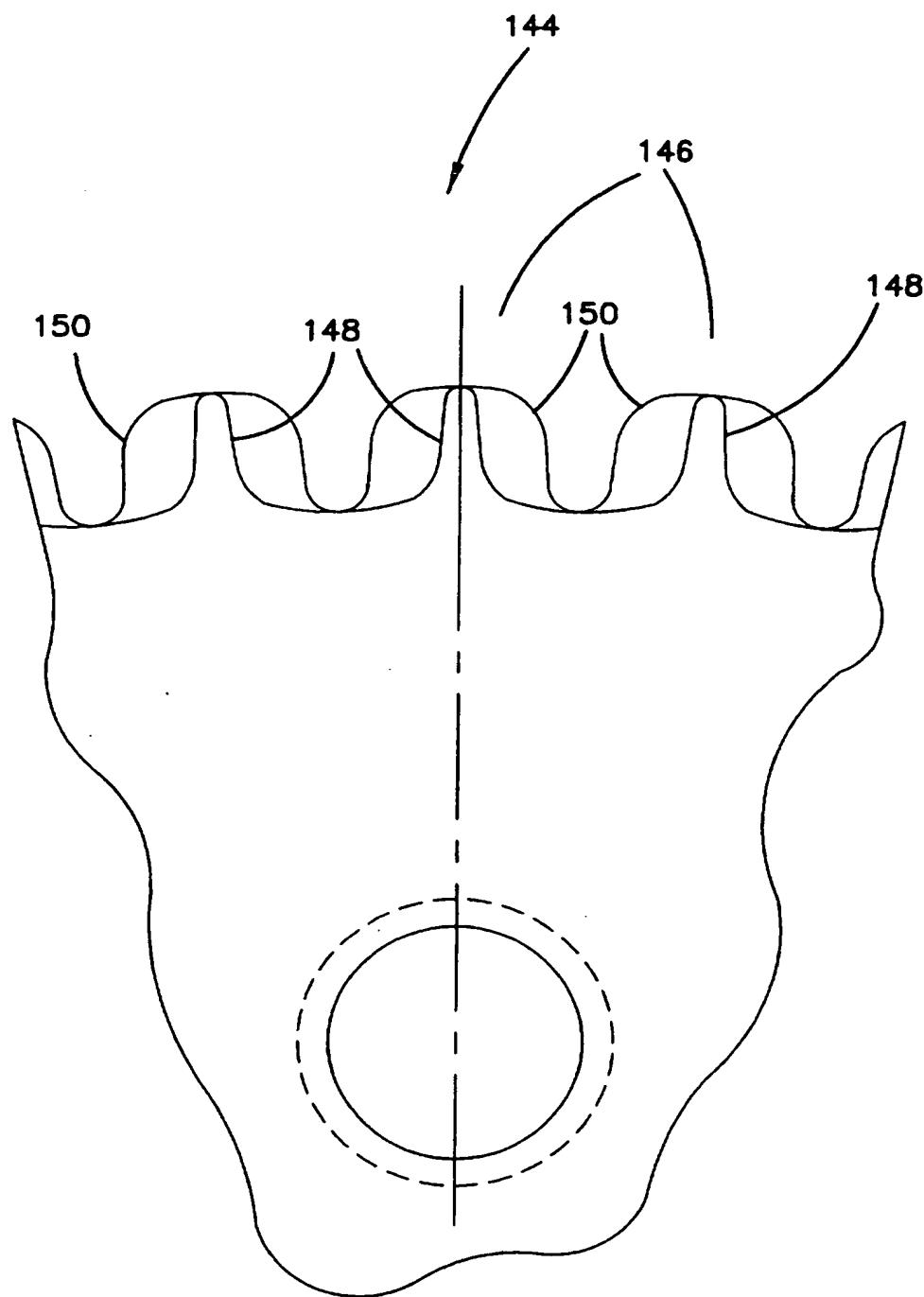


FIG. 5

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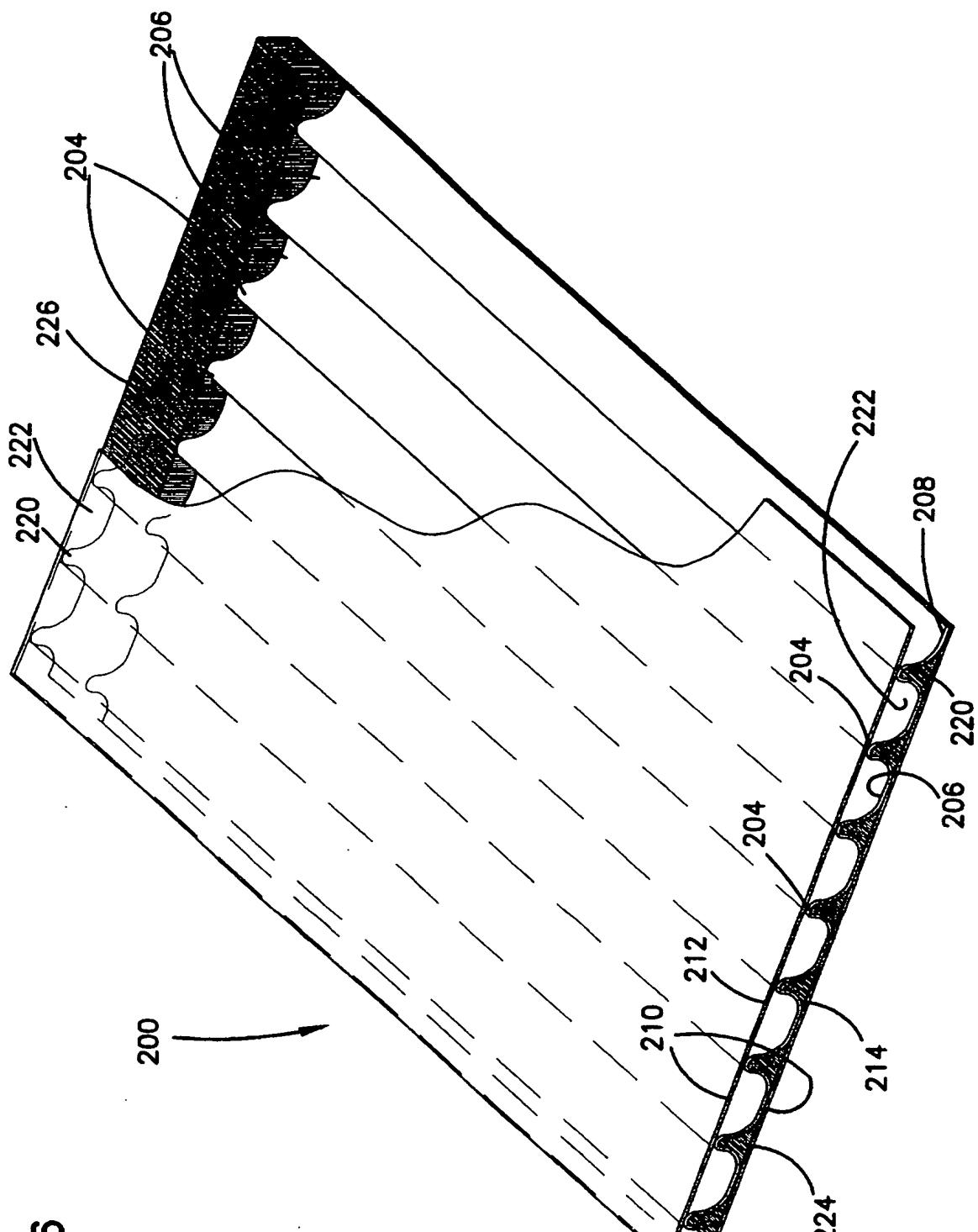


FIG. 6

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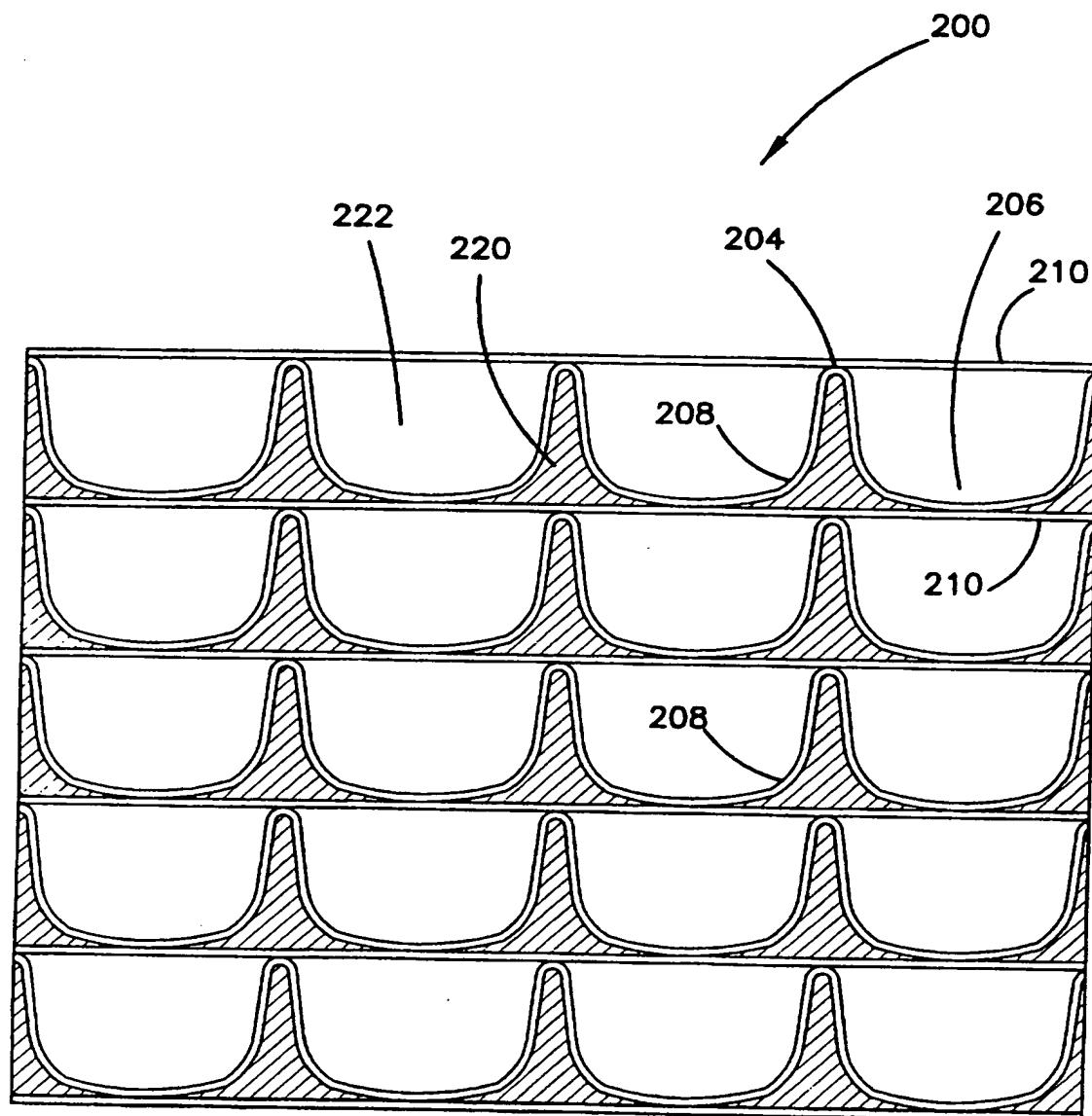


FIG. 7

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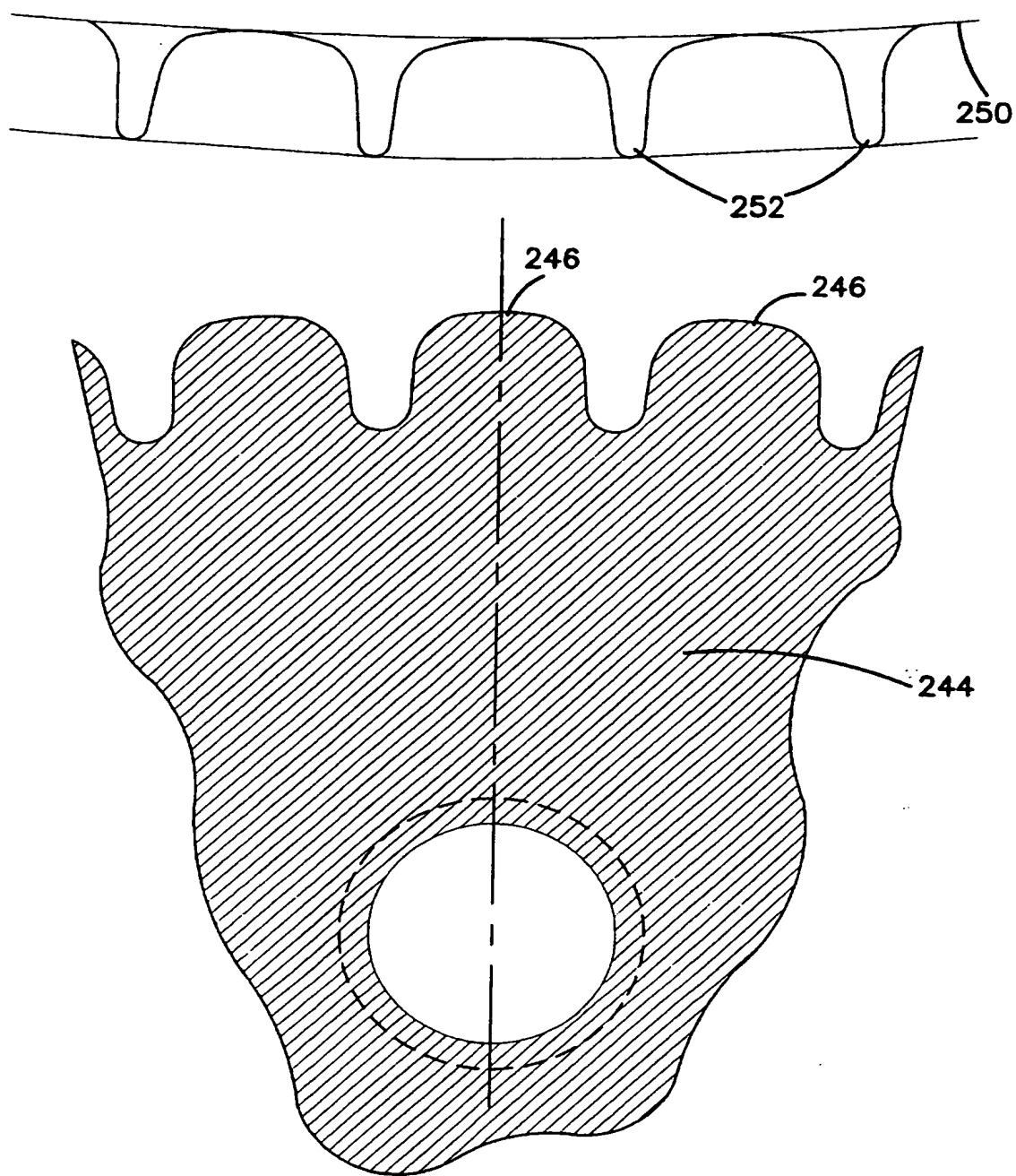


FIG. 8

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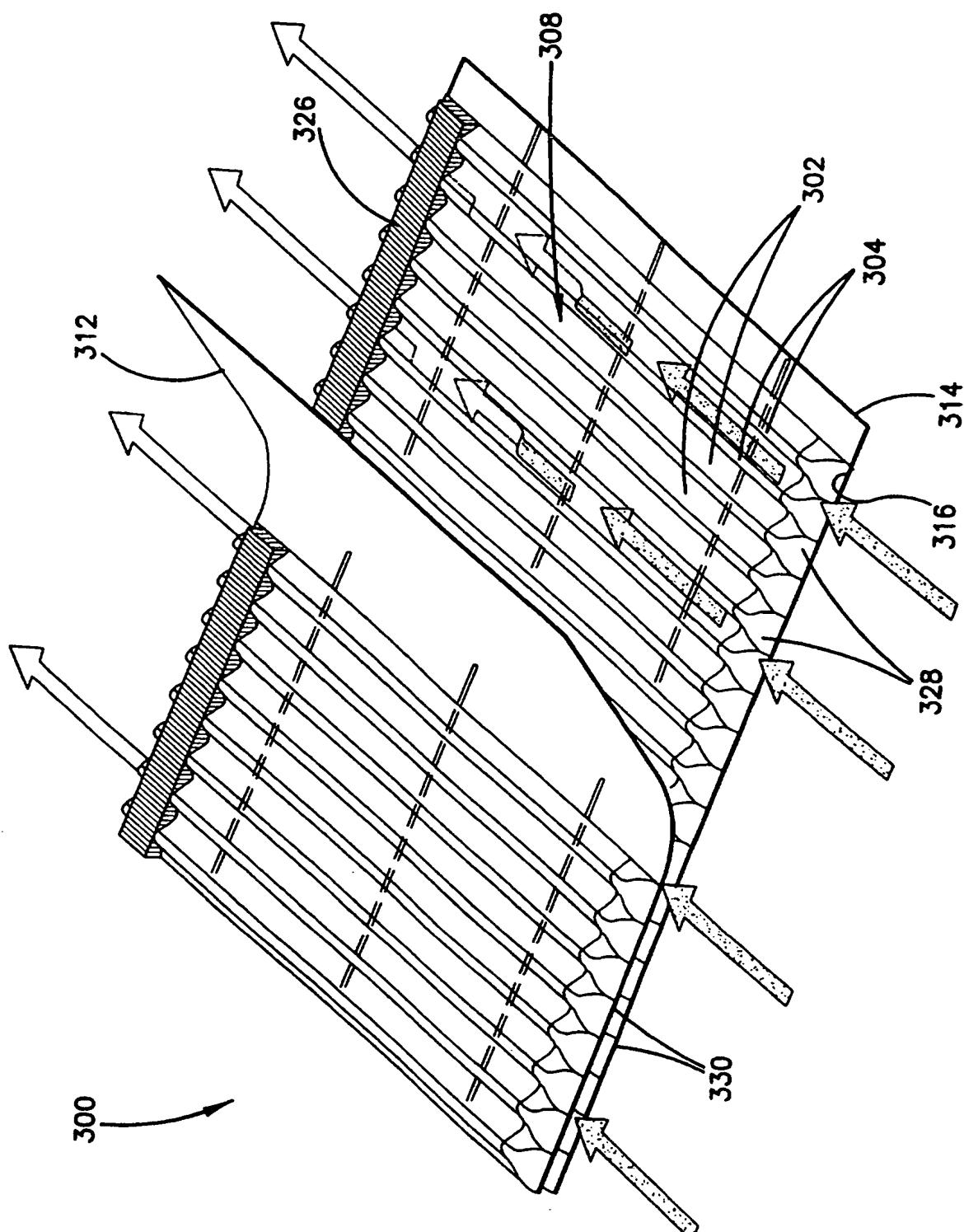


FIG. 9

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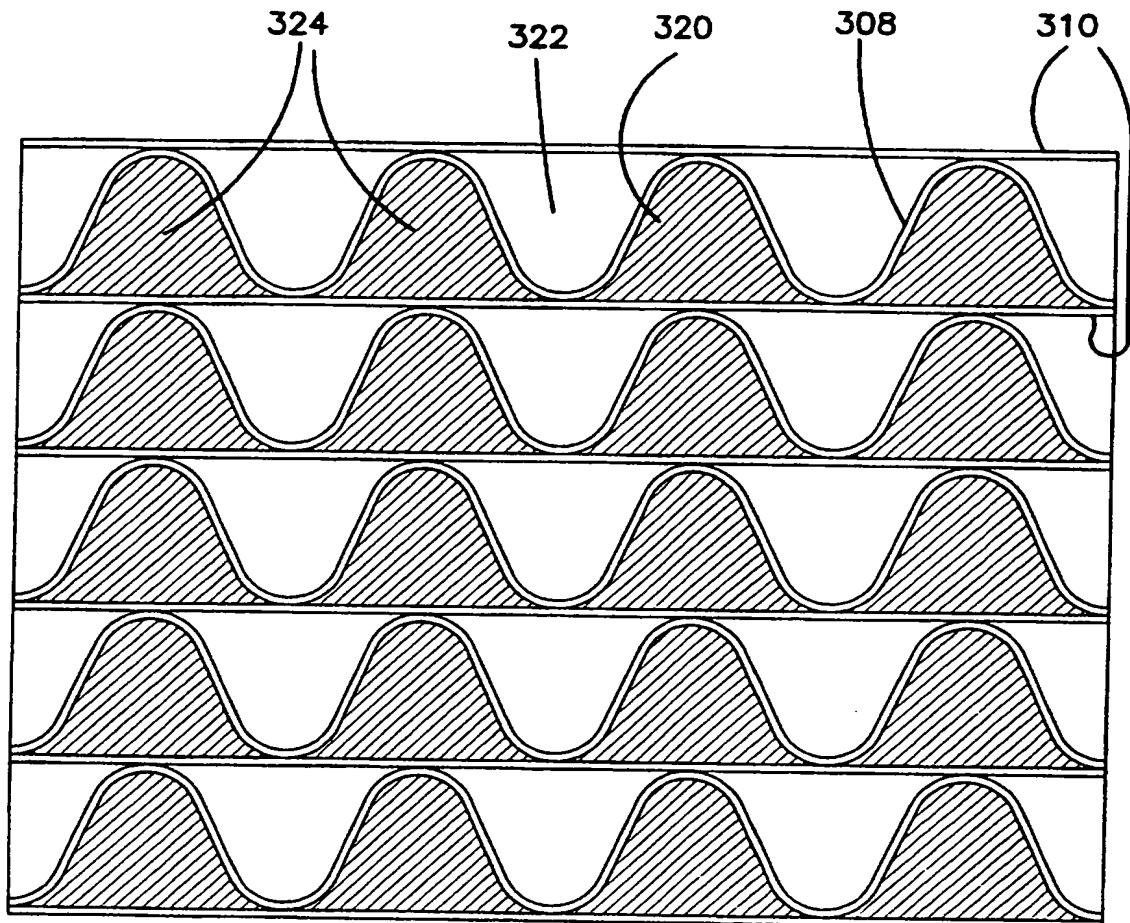


FIG. 10

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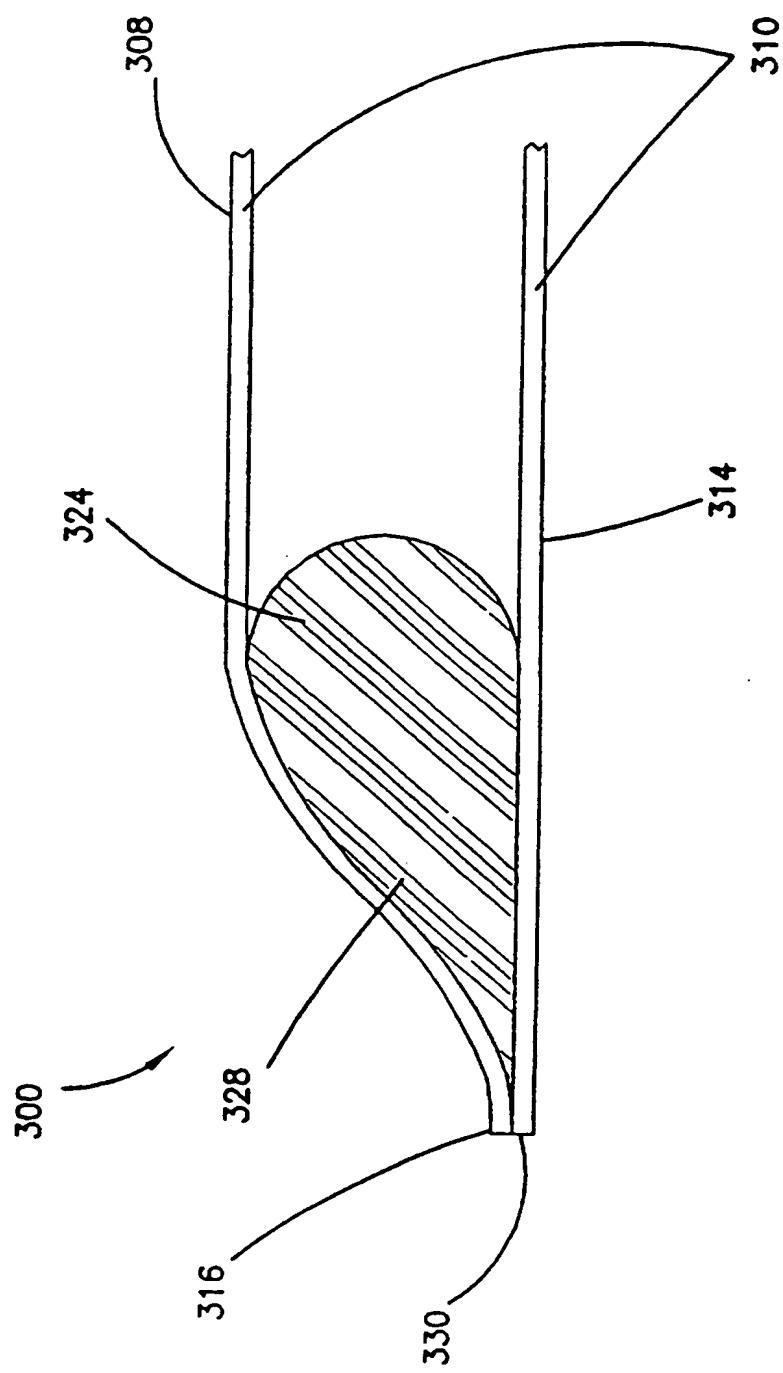
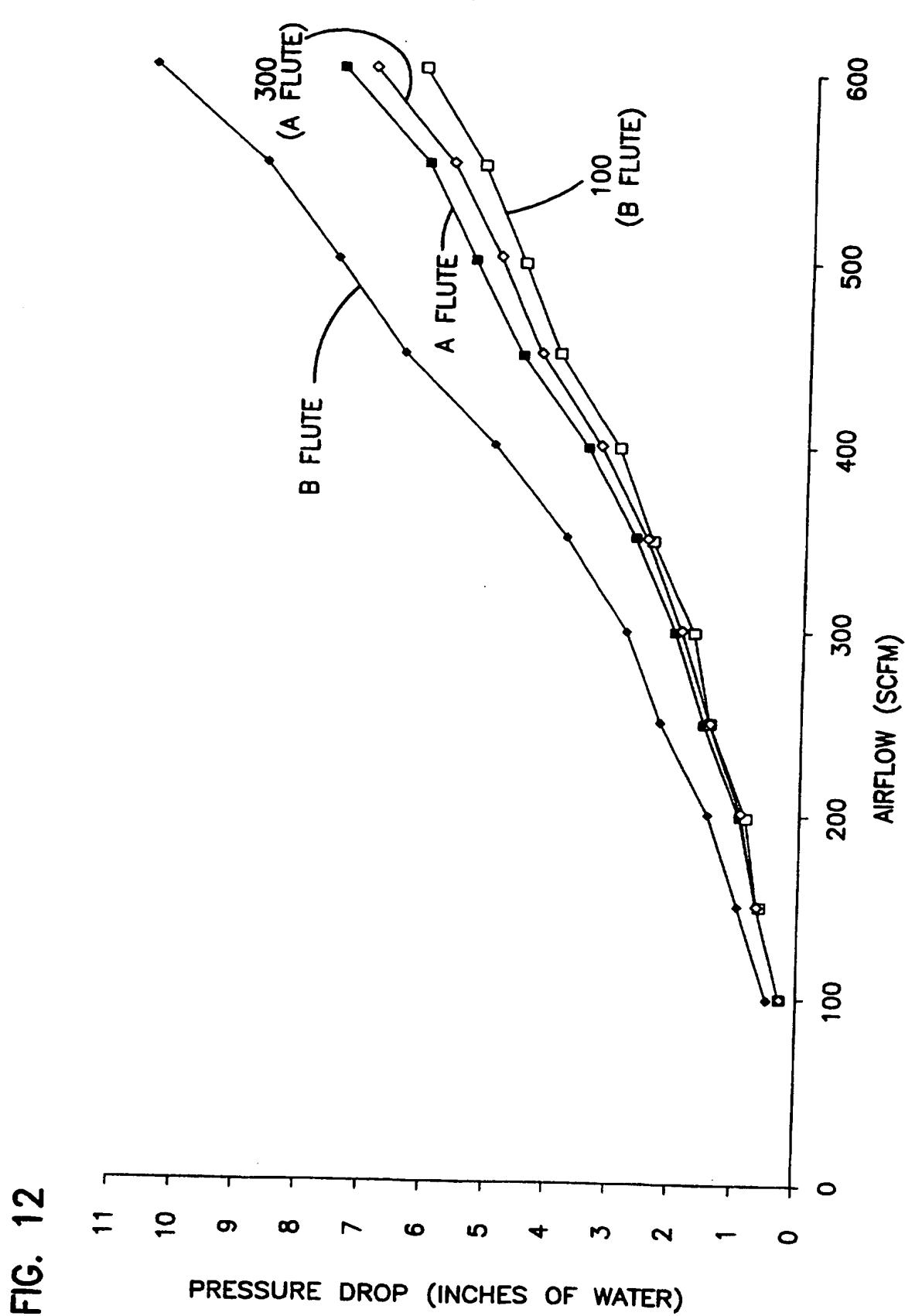


FIG. 11

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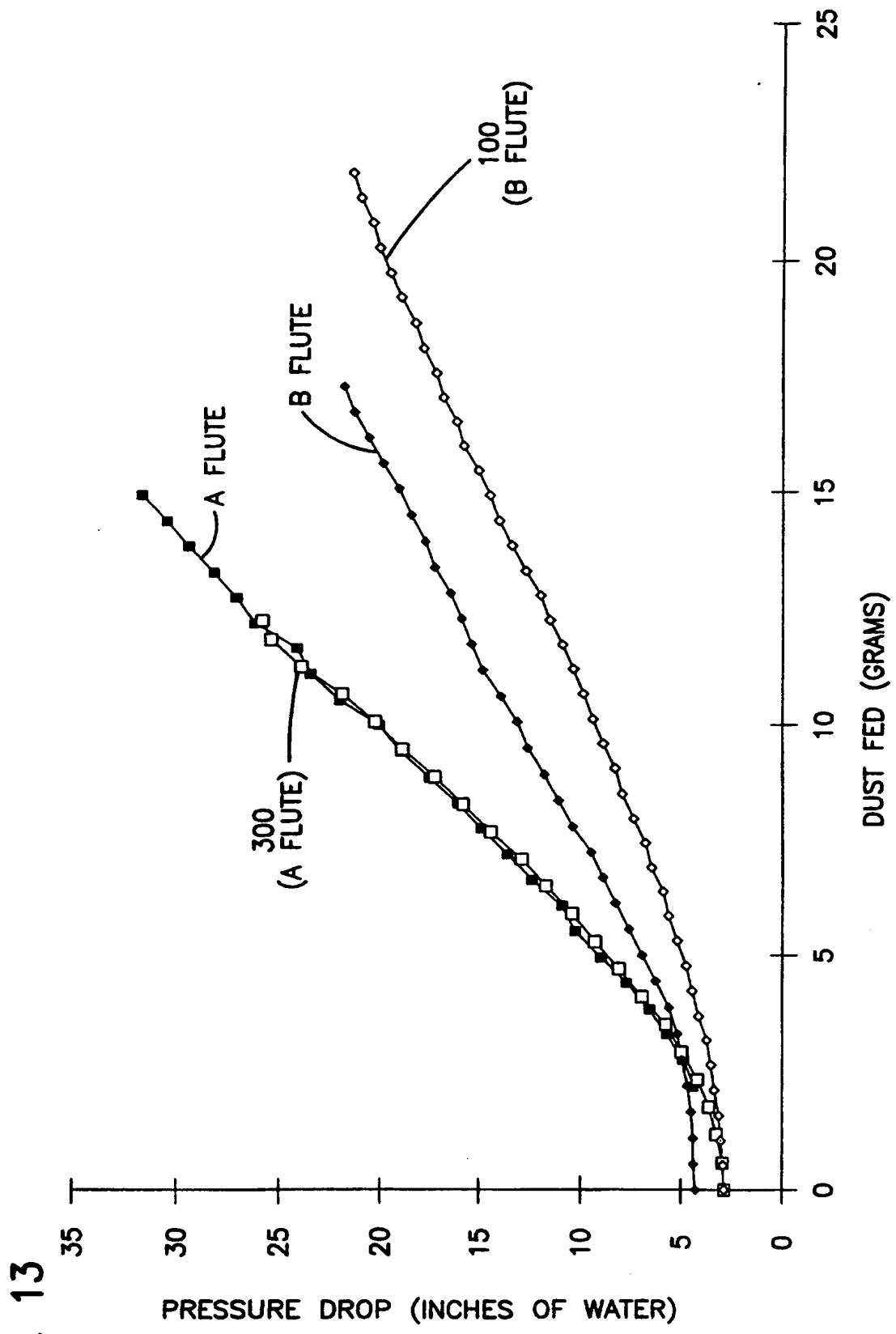


FIG. 13

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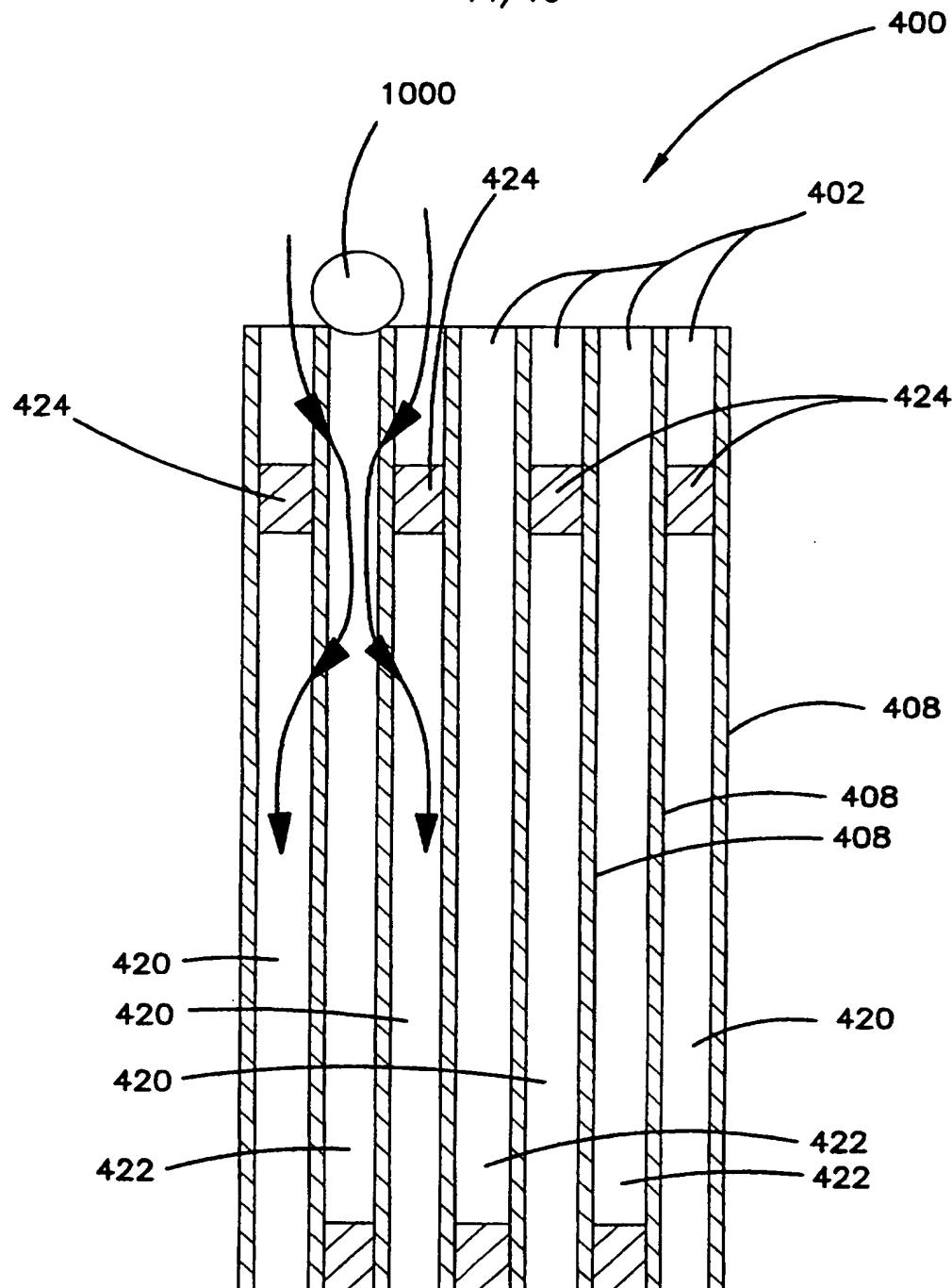


FIG. 14

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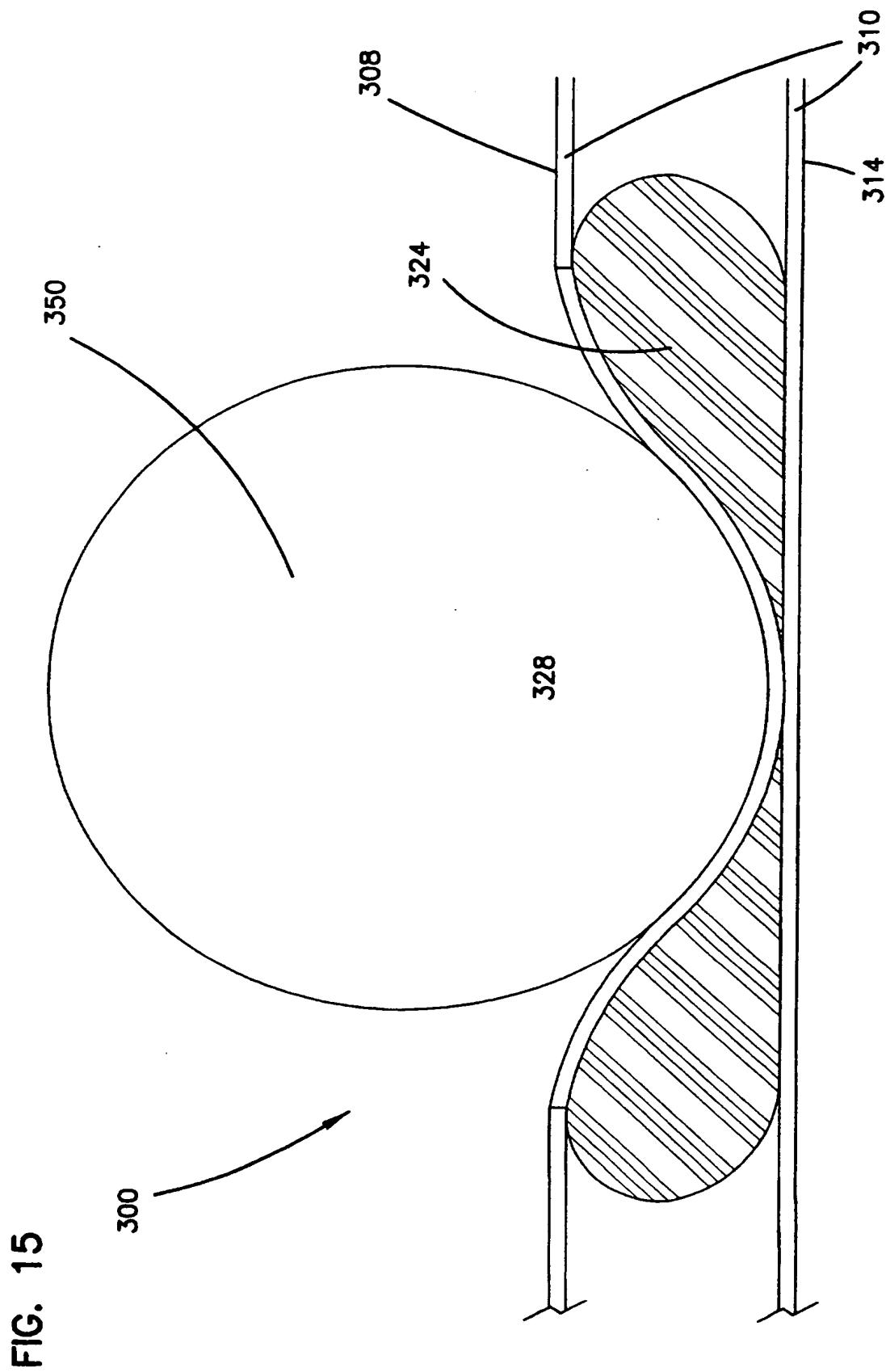
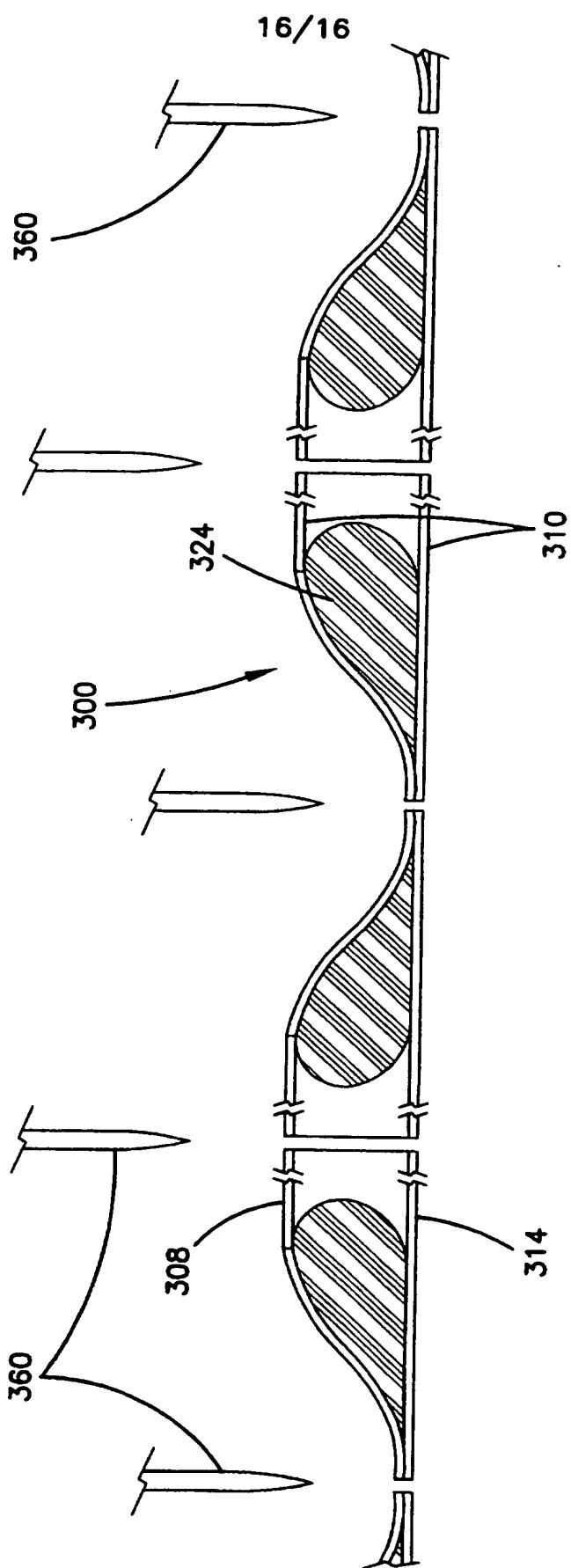


FIG. 15

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**FIG. 16****SUBSTITUTE SHEET (RULE 26)**

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 97/07050

**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 6 B01D46/12 B01D46/52 B01D25/24

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
 IPC 6 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 630 672 A (NIPPON DENSO CO) 28 December 1994  see the whole document ---	1,2, 4-11,14, 18-22, 24-26
X	US 4 310 419 A (NARA AKIO ET AL) 12 January 1982  see the whole document ---	1-11,14, 18-22, 24-27
A	US 3 025 963 A (BAUER) 20 March 1962  see the whole document ---	1,15-17, 23, 28-32, 34-37
		-/-

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

\* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
21 August 1997	12.09.97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Authorized officer  Cubas Alcaraz, J

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 97/07050

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 589 983 A (WYDEVAN ROBERT M) 20 May 1986 see the whole document ---	1-3,7, 12,13
A	US 4 652 286 A (KUSUDA TAKAO ET AL) 24 March 1987 see the whole document ---	1-37
A	US 2 599 604 A (BAUER ET AL.) 10 June 1952 see the whole document -----	1,15-17, 23,28-32

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